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Automatic assembly of wind load from BIM-model

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Abstract. In recent years many Russian construction companies have started using technologies of building information modelling (hereinafter – BIM). It's a global trend aimed at maximum automation and acceleration of a design process and documentation approval. This article shows main advantages of the BIM approach, discusses the possibility of expanding "the space of benefits" by using digital building models for wind load simulation (automatization of this process). Currently, applied methods of wind impact analysis based on which automation is possible are described. Potential application scenarios, describing the advantages of automatic wind load assembly, are listed. Also, possible approach to the analysis of loads in process of BIM-design is shown.

1. Introduction

Information modeling technologies (or BIM technologies) are gaining more and more popularity in Russia. Thanks to state support (in particular, "The Order of the President of Russia on the transition to a life cycle management system for capital construction projects by introducing information modeling technologies" [1]) and the opportunities to facilitate the work of investors, designers, surveyors, builders through the implementation of the advantages shown below, the BIM "zone of influence" will continue to develop in the future.

2. Relevance and scientific merit of the subject

At the current stage of technology implementation, the following main advantages of BIM modeling are often emphasized:

- a visual display of the main parameters of the object at the stage of outline design;
- the ability to conveniently coordinate the work of various specialists on one object;
- the possibility of checking for collisions (unacceptable geometric intersections of model objects, violations of normalized distances between them);
- the ability to visualize design decisions to simplify decision making;
- the ability to simplify the process of creating a construction schedule (4D BIM);
- the possibility of significantly simplifying the process of developing estimates for the facility (5D BIM);
- the possibility of more accurate and visual control over the construction process (in particular, when applying laser scanning of the actually erected part of the building);



- the ability to conveniently monitor the status of assets during the operation of the capital construction facility;
- the ability to conveniently monitor the state of engineering systems of the building during operation (for example, when using sensors to control the parameters of objects, information from which will be clearly displayed in the model space).

The indicated main advantages are certainly significant, but it is important to remember that, in fact, the building's information model is a "set of zeros and ones" stored in the computer's memory, and this opens up endless possibilities for searching and implementing new optimization options and simplifying work with the model. The symbolic graphic designation of the "advantage space" of BIM is shown in the figure (Figure 1).

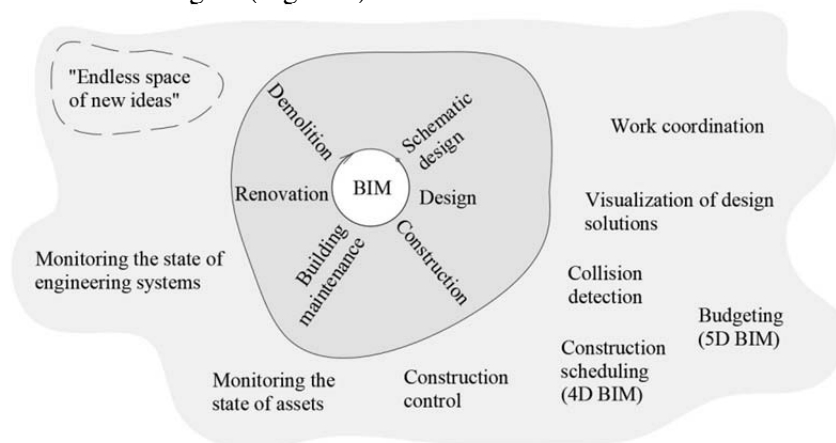


Figure 1. Graphical representation of the BIM Benefit Space.

The relevance and versatility of the topic of information modeling can be judged by numerous studies conducted by members of the community. For example, we can mention the materials of the ICCATS 2019 conference [2], the materials of the BIMAC 2018-2020 conferences [3-6], BIM was considered at the ANTOK Youth Scientific Conference [7]. Speeches at the Autodesk University conference [8-12] may be of particular interest.

This article discusses only one of the areas of application of BIM - the use of the building information model when performing design calculations. Attention is focused on finding ways to optimize the construction process in this area.

3. Formulation of the problem

An important task in the design of buildings and structures is their calculation of strength and stability. In modern conditions, special settlement systems (Lira-CAD, Ing +) help to reduce the calculation time and increase their accuracy. Currently, active work is underway on the possibility of communicating between calculation programs and programs for BIM-design (for example, the implementation of two-way integration of LIRA-SAPR with Autodesk Revit [13]).

However, the calculations are not fully automated. Designers have to spend a considerable amount of time and effort on compiling the initial data for calculation: on collecting and systematizing the loads, on their modeling (the correct application to the design scheme). In particular, it takes a lot of time to collect wind loads.

At the same time, in the process of BIM design, a model is created that already contains a significant amount of data for the automated modeling of wind load (building height, its surface shape, spatial orientation, walling material, etc.). It is also possible to add additional necessary information to the BIM-model (geographical location, type of terrain). Thus, with minor refinement, you can get a model of the building that will contain enough information to automatically simulate wind loads.

The research task was to find a way to simplify and automate the collection of wind loads through the use of information modeling technologies.

4. Theoretical part

For the correct automation of any process, it is important first of all to understand its essence, its logic, for this it is necessary to consider what methods of setting the wind load are used today.

Currently, there are two main approaches to modeling wind load:

- mass, “manual” method (compliance with minimum regulatory requirements);
- analysis of complex special cases using special software (for example, COMSOL Multiphysics, Autodesk CFD).

These approaches can underlie the creation of a method for collecting wind load from the BIM model.

Consider the first approach. The main regulatory requirements for the collection of loads in Russia are set out in the document SP 20.13330.2016 “Loads and effects” [14]. To comply with Russian standards, the result of the collection of loads must take into account:

- the main wind load;
- the peak values of wind load;
- the resonant vortex excitation;
- aerodynamically unstable vibrations such as galloping, divergence and flutter.

You can also highlight what information about the building is needed (should be contained in a digital model) for the possibility of calculating the wind load according to the requirements of the set of rules:

- the geographical location of the building;
- the height of various structures above ground level;
- the dimensions of the building in plan;
- type of terrain (characterized by protection from the wind);
- the shape of the building.

It is worth paying special attention to the fact that the rulebook contains an indication of the need to take into account aerodynamically unstable vibrations such as galloping, divergence and flutter, but there are no rules or criteria for taking them into account. To clarify this feature, it is advisable to study another document - MDS 20-1.2006 "Temporary recommendations for the designation of loads and effects acting on multi-functional high-rise buildings and complexes in Moscow" [15].

The methodological document provides a classification of wind effects, spells out an algorithm for determining the average and ripple components of the wind load, shows a formula for determining the peak values of the wind load (these calculations correspond to the same ones given in the set of rules), also shows the calculation of the intensity of the effect of resonant vortex excitation, the conditions for the manifestation of such effects like galloping or divergence.

Sometimes, when designing more complex, unique objects, it becomes necessary to conduct more detailed and complex calculations. It is possible to conduct tests in wind tunnels or simulate wind effects in special programs (such as COMSOL Multiphysics, Autodesk CFD or ANSYS). It is not advisable to associate model tests with the BIM model from the point of view of automation of calculations, therefore consider in more detail the use of these programs.

The use of COMSOL Multiphysics for calculating wind exposure is considered in the article “Visual modeling of the wind load of the reflector of a parabolic communication antenna in the COMSOL Multiphysics software package” [16].

The COMSOL software package uses the finite element method to solve numerical equations. To solve the problem, it is necessary to choose the volumetric calculated plane (for example, “a parallelepiped with dimensions much larger than the object of study”), choose a model that characterizes the physical process (in this case, “a model of turbulent flow with a $k-\omega$ interface of equations, boundary conditions and volumetric forces”). The program simulates the object and the computational grid, then the calculations are performed. As a result, the distribution of speed, pressure, and emerging wind turbulence becomes known.

In Autodesk CFD, it is possible to create a calculation model based on the imported three-dimensional model. Using the calculation model, the program will generate a calculation grid, and the CFD and CFD2 solvers will calculate the pressure from the action of the wind. The program also contains tools for analysis and visualization of results [17,18].

A variant of modeling wind influence was also considered in the article “Refinement of the methodology for determining the wind load for objects of parametric architecture” [19]. Here, the analysis of wind exposure is proposed to be performed in the «Fluent» module of the ANSYS software package.

To analyze the wind impact, “A computational domain with dimensions of $400 \times 1000 \times 200$ m is created with a breakdown in the “Mesh” submodule of the computational space into finite elements, followed by subtraction of the three-dimensional model of the building”. As a result, wind speed and wind pressure are obtained.

Analysis of various options for orienting the building to the cardinal points using the ANSYS software package is given in the article “Calculation of buildings of complex geometric shape for wind effects” [20].

For practical application, it is advisable to combine the considered approaches, the area of possible interaction is shown in the figure (Figure 2).

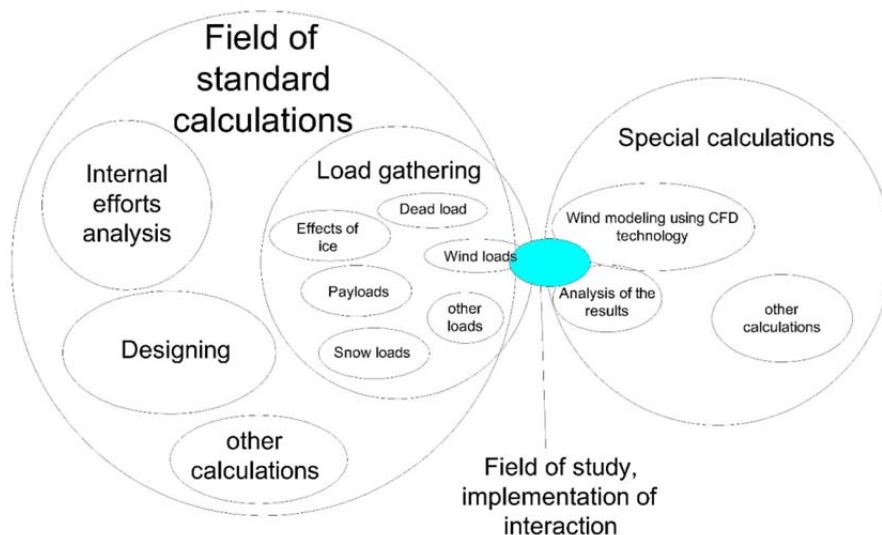


Figure 2. Graphical representation of the field of study.

The bulk of BIM design software could create extensions (or plugins). For example, one of the most popular programs for creating BIM models, Revit from Autodesk, has an application programming interface (API) that allows you to integrate applications written in any .NET language (a language that meets the requirements of the CLI - common language infrastructure specification) into the main program space. Based on this possibility of BIM-programs, it is advisable to create an extension that "collects the wind load".

Most programs for BIM-design (in particular - Autodesk Revit) have the ability to create extensions (or plugins). Given the above approaches, it is advisable to create a plug-in that would allow you to determine the wind load on the building (or rather, on its BIM-model) at any point on the surface.

The structure of the work of such an extension could be previously described as follows:

1. request for estimated wind direction;
2. the collection of necessary data on model elements exposed to wind (height above ground level, surface area of such elements as external walls, floor and floor slabs, parapets);
3. the request for additional necessary data (geographical location, type of terrain);

4. the calculation of wind pressure on the considered elements (on all or some of them) using, for example, formulas from the above set of rules and the methodological document [14, 15];
5. the output of wind pressure values for various points of the building surface (in the form of a specific value for the requested point or in the form of isopoles).

It would also be advisable to “teach the plug-in” to determine special conditions (significant building height with a small built-up area, complex surface shape, etc.) that require more complex calculation using special software (COMSOL Multiphysics, Autodesk CFD, ANSYS). A useful function in this case could be a bundle with one of these programs (for example, the ability to import a three-dimensional model into Autodesk CFD).

5. Practical significance

The benefit of creating and using such an extension is to reduce the time required for calculations and to increase the accuracy of the results. Use is possible both in the general calculation of the building for strength and stability in the early stages of project development, and in the calculation and construction of individual structures (such as external walls, floor slabs or parapet completion of the building). A separate area of use is the design of curtain wall systems and the calculation of the details of their fastening.

It is important to note that the idea considered has significant potential for development, because not only the process of assembling the wind load can be automated. Modeling of snow effects, payloads (for example, from equipment, people, animals, stored materials and products, vehicles, overhead cranes and overhead cranes), ice loads, and temperature effects is worthy of similar improvement.

The main way of the idea of automating the collection of loads using the BIM model could be the creation of separate plug-ins for individual types of loads and their subsequent combination. With the successful implementation of these plans, the process of calculating buildings for strength and stability will take significantly less time. Schematically, such a process is shown in Figure 3.

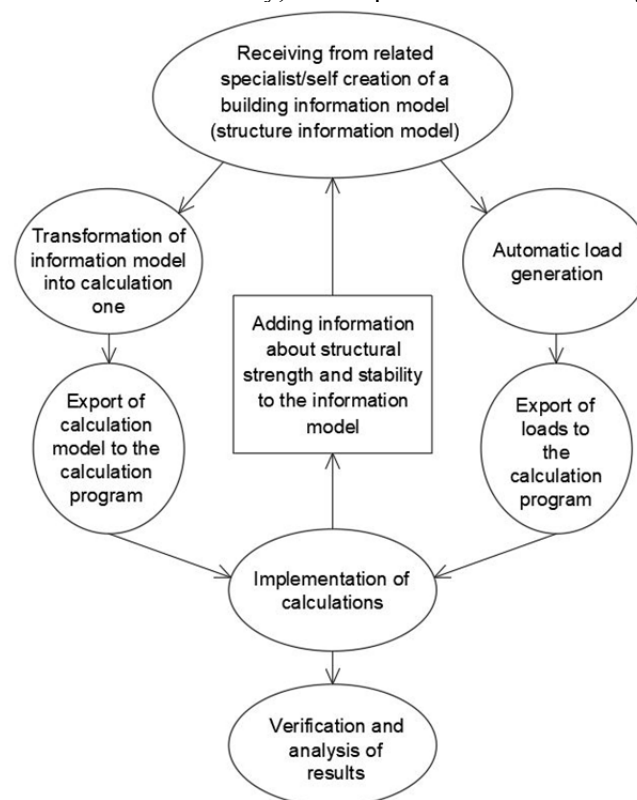


Figure 3. Calculating the building for strength and stability when using BIM.

It is also advisable to create similar extensions for various programs used in BIM-design:

- Autodesk Revit;
- Renga;
- ArchiCad;
- AllPlan;
- Tekla.

6. Conclusion

The obvious benefit of using the plugin that is proposed to be developed will be the saving of time for designers by automating the process of modeling and collecting loads and saving materials due to increased accuracy.

References

- [1] The order of the President of the Russian Federation of July 19, 2018 No. Pr-1235 “On the transition to the life cycle management system of capital construction projects by introducing information modeling technologies in order to modernize the construction industry and improve the quality of construction”. <http://docs.cntd.ru/document/550966183>
- [2] Maleeva T, Selyutina L and Frolova N 2019 Use of modern technology of information modeling in capital construction object life cycle management *Int. Conf. on Construction, Architecture and Technosphere Safety (ICCATS 2018)*
- [3] Belyakov V A, Galiahmetov R T and Salnikov V B 2019 The features of design and calculation of the cost of construction of the facility in the implementation of BIM technology *BIM in construction & architecture (BIMAC 2019)* pp 107–112
- [4] Slizh V D, Kim V V, Pridvishkin S V, Salnikov V B 2020 Generative design in a modern approach to design in construction *BIM in construction & architecture (BIMAC 2020)* pp 161–165
- [5] Chertushkin A D, Pridvishkin S V, Salnikov V B 2020 Methods for calculating fire risk in the information model of a building in Russia *BIM in construction & architecture (BIMAC 2020)* pp 181–185
- [6] Sukhanov K O and Samoletov M V 2019 Problems of interaction of program complexes in the process of working with the information model of building *BIM in construction & architecture (BIMAC 2019)* pp 184–188
- [7] Kim V V and Salnikov V B 2019 Automation of solar irradiation calculation in building design *AKSTS young generation conf.* pp 12–16
- [8] Chonkan L Revit modeling strategy for successful CFD Analysis: an iterative approach 2019. <https://www.autodesk.com/autodesk-university/class/Revit-modeling-strategy-successful-CFD-Analysis-iterative-approach-2019>
- [9] Hoffman M 2014 Building Information Modeling and Virtual Design and Construction for Executives. <https://www.autodesk.com/autodesk-university/class/Building-Information-Modeling-and-Virtual-Design-and-Construction-Executives-2014>
- [10] Menken N 2019 Getting BIM into the Field. <https://www.autodesk.com/autodesk-university/class/Getting-BIM-Field-2019>
- [11] Makarev N 2019 Revit Best Practices in Cast-in-Place and Precast Structure Engineering. <https://www.autodesk.com/autodesk-university/class/Revit-Best-Practices-Cast-Place-and-Precast-Structure-Engineering-2019>
- [12] Keinonen P 2019 Getting MEP Designers Ready for BIM. <https://www.autodesk.com/autodesk-university/class/Getting-MEP-Designers-Ready-BIM-2019>
- [13] LIRA-SAPR knowledge base. Two-way integration with Autodesk Revit. <https://help.liraland.ru/829/3441/>

- [14] SP 20.13330.2016 Loads and impacts. The updated edition of SNiP 2.01.07-85 * (as amended No. 1, 2). <http://docs.cntd.ru/document/456044318>
- [15] MDS 20-1.2006 Temporary recommendations for the designation of loads and effects acting on multi-functional high-rise buildings and complexes in Moscow. <https://files.stroyinf.ru/Data1/47/47881/>
- [16] Sarsikeev E Zh, Lyapunov D Yu, Bobikhov R S and Petrusev A S 2014 Visual modeling of the wind load of the reflector of a parabolic communication antenna in the COMSOL Multiphysics software package *Modern problems of science and education* **3**. <https://science-education.ru/ru/article/view?id=13668>
- [17] Autodesk CFD - functional, full description. <https://www.pointcad.ru/product/autodesk-simulation-cfd/>
- [18] Kutukov A S 2011 Innovative flow and heat transfer analysis in 3D CAD models using Autodesk Simulation CFD *CADmaster* **5**. https://www.cadmaster.ru/magazin/articles/cm_60_15.html.
- [19] Kravchenko G M, Trufanova E V and Poletaev M V 2019 Refinement of the methodology for determining the wind load for objects of parametric architecture *Engineering Bulletin of the Don* **3** http://www.ivdon.ru/uploads/article/pdf/IVD_129_kravchenko_trufanova_poletaev.pdf_d712fcd245.pdf
- [20] Agakhanov E K, Kravchenko G M, Osadchiy A S and Trufanova E V 2017 Calculation of buildings of complex geometric shape on wind effects *Bulletin of the Dagestan State Technical University. Technical science* **2** 8–17